Field volatility of Dicamba

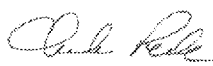|	
Report:	MRID 51111901. Griese, W. Off-target Movement Assessment of a Spray Solution Containing MON 76980 + MON 79789 + Intact™ + MON 51817 – Illinois. Unpublished study performed by Lange Research and Consulting, Inc, Fresno, California; Eurofins EAG Agroscience, LLC, Columbia, Missouri; Exponent, Inc., Alexandria, Virginia, and AGVISE Laboratories, Northwood, North Dakota; sponsored and submitted by Monsanto Company, Chesterfield, Missouri. Lange Study ID: LR19397. Eurofins Study ID: 89311. AGVISE Study ID: 19-1371, 19-115. Monsanto Study ID: REG-2019-0035. Reference No.: TRR0000087. Experiment initiation May 31, 2019 and completion April 3, 2020 (p. 8). Study and Report completion April 3, 2020.
Document No.:	MRID 51111901
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with U.S. EPA FIFRA GLP standards (40 CFR Part 160) with the exception of test site observations, slope estimates, pesticide and crop history, soil taxonomy, test plot preparation, nozzle calibration, air modeling, and study weather data (p. 3). Signed and dated Data Confidentiality, GLP Compliance, and Quality Assurance were provided (pp. 2-5). An Authenticity Certification statement was not included.
Classification:	This study is **acceptable**. Monitoring started after the conclusion of application. An independent laboratory method validation was not conducted. Minimum fetch requirements were not always met for the aerodynamic method, but this is not expected to significantly impact the derivation of the flux rates. A significant rain event (2 in) occurred between hours 36 and 48, making the flux estimates generated during and after this period uncertain.
PC Code:	128931
EPA Reviewer:	Chuck Peck Senior Fate Scientist	Signature: Date:	2020.10.25 06:28:30 -04'00'
EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist	Signature: Date:	2020.10.25 13:00:37 -04'00'

Executive Summary

Field volatilization of dicamba formulation MON 76980 when tank mixed with glyphosate potassium salt (MON 79789), Intact™ (polyethylene glycol, choline chloride, and guar gum), and potassium acetate (MON 51817) was examined from a single dicamba-tolerant soybean-cropped test plot surrounded by non-dicamba tolerant soybean in Clinton County, Illinois. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. The products were applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-

target plants. A control plot was established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures and relative humidity the day of application (7/2/19) ranged from 22.3-33.4°C (72.1-92.1°F) and 46-97%, respectively. Air temperatures and relative humidity ranged from 19.2-33.8°C (66.6-92.8°F) and 46-100%, respectively, 1 to 7 days after application. Soil temperatures were not reported.

Under field conditions at the test plot, based on calculations using the Indirect method, peak volatile flux rates of 0.000547 and 0.00030 $\mu g/m^2 \cdot s$ were estimated by the reviewer and study authors, respectively, accounting for 0.014% and 0.010% of the applied dicamba observed 0.4 to 5.4 hours post-application. By the end of the study, a total of 0.069% and 0.046% of dicamba volatilized and was lost from the field, as estimated by the reviewer and study authors, respectively.

Under field conditions at the test plot, based on calculations using the Integrated Horizontal Flux method, a peak volatile flux rate of 0.000139 $\mu g/m^2 \cdot s$ was estimated by the reviewer and the study authors, accounting for 0.005% of the applied dicamba observed 0.6 to 6 hours post-application. By the end of the study, a total of 0.015% of dicamba volatilized and was lost from the field.

Under field conditions at the test plot, based on calculations using the Aerodynamic method, a peak volatile flux rate of 0.000679 $\mu g/m^2 \cdot s$ was estimated by the reviewer and study authors, accounting for 0.023% of the applied dicamba observed 0.6 to 6 hours post-application. By the end of the study, a total of 0.036% of dicamba volatilized and was lost from the field.

Spray drift measurements indicated that dicamba residues were not detected in any of the upwind and right wind samples at one hour after application and were detected at a maximum fraction of the amount applied of 0.006928 in the downwind and left wind samples. Deposition of dicamba above the no observed adverse effects concentration (NOAEC) was detected in all transects of the downwind and two transects of the left wind direction in the one-hour sampling period. Study authors estimated distances from the edge of the field to reach NOAEC for soybean (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) ranged from 10 to 18.1 m in the downwind direction and 12.7 to 1.5 m in the left wind direction. Reviewer-estimated distances ranged from 8.3 to 12.3 m and 9.7 to 15.8 m in the downwind and left wind directions, respectively.

Figure 1   **Volatile flux – Soybean Plot**
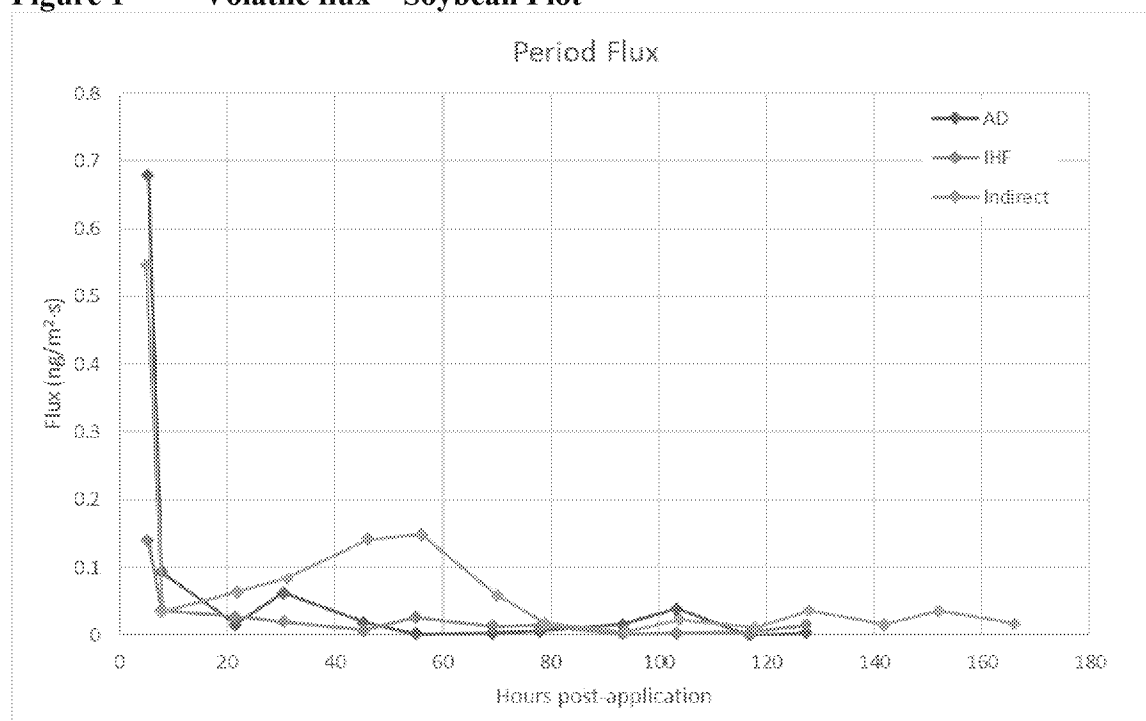
Plant effects (51111901, EPA Guideline 850.4150; Supporting files in Appendix 2)

The effect of MON 76980 (DGA salt of dicamba), MON 79789 (potassium salt of glyphosate), Intact (a drift reduction agent), and MON 51817 ("*Vaporgrip X*") on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.50 lb ae/A and Glyphosate were 1.125 lb ae/A. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application and post-application tank solutions; nominal and measured application rates are provided in Table 4. On day 28 the surviving plants along several transects projecting from the treated area were measured for height and visual signs of injury.

There are several concerns with the conduct and conditions of this study. In terms of the utility of the volatility transects (covered transects), a significant rain event (2 in) occurred between hours 36 and 48, reducing the emissions from volatility. This reduction impacts the amount of material that the transects may have been exposed to via volatilization. Distances based on vapor exposure alone (covered transects) will reflect plant responses to this lowered exposure and may underestimate distances under conditions of no rainfall.

There are signs of dicamba movement with runoff following the rainfall events. Both RW transects and the NE transect showed significant impacts to plant height and VSI as related to exposures through runoff.

Spray Drift + Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions. Height effects and visible signs of injury (VSI) were recorded up to 28 days after spray application of the tank mix.

Regression based distances to a 5% reduction in plant height were evaluated for each individual transect. The plant height data from control plots were used to establish the baseline 5% effect level plant height.

Visible symptomology was reported, but the specific phytotoxic symptoms were not. VSI distances were established based on regression estimated distances to a 10% VSI. The downwind spray drift (uncovered) transects was had significant VSI with distance relationships. In the DWC, LWA, LWB, and NW transects reaching out to 24.7 m. Spray drift transects decreased with increased distance from the treated area ranging from 5 to 50% at 5 m and 0 to 5% at 60 m.

Significant reductions in plant heights were also observed to have strong distance to effect patterns (i.e., more reduction closer to the treated area) in areas downwind of the treated area (e.g., DW, LW and NW transects, **Table 1**). Although the study author attempted to minimize variability by selecting plot distances that had plants of similar height at the start of the study, plant height differed across the field due to responses of the condition of the field (notably soil moisture in low areas). Therefore, due to the non-uniformity of plant height across the field, there is uncertainty in the distance estimates based on a 5% reduction relative to the control growth.

Furthest distance to 5% Reduction in Plant Height = 59.2 meters (194.2 feet)
Furthest distance to 20% VSI = 24.7 meters (81.0 feet)

Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, and 20 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions and isolated using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. Height effects and visual symptomology was recorded up to 28 days after spray application of the tank mix. Similar to the uncovered transects, covered RWA and RWB were impacted by dicamba contaminated runoff.

When compared to the negative control plot, the study author and reviewer found no significant inhibitions in plant height at any distance in any direction in the volatility samples. Transect DWA did suggest a 16.9 m distance however the data are confounded by a high background variability in plant heights across the field. Furthermore, there was no VSI observed, so it is unlikely that exposure to dicamba was the cause. The percent of visible symptoms were slight ($\leq$10%) and there was no dose response.

Furthest distance to 5% Reduction in Plant Height = 3 meters (<9.8 feet)
Furthest distance to 10% VSI = <3 meters (<9.8 feet)

Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

Exposure pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height	Distance to 10% VSI	Distance to 5% Height	Distance to 10% VSI
DWA	36.6[a]	<5[b]	16.9[a]	<3[b]
DWB	76.1[a]	<5[b]	>20[b]	<3[b]
DWC	37.3[a]	8.4[a]	<20[b]	<3[b]
LWA	>60[b]	13.4[a]	<10[b]	<3[b]
LWB	59.2[a]	11.1[a]	>20[b]	<3[b]
NE[c]	<40[b]	<40[b]	-	-
NW	35.9[a]	24.7[a]	-	-
RWA[c]	>60[b]	>50[b]	4.5[a]	22.6[a]
RWB[c]	<3[b]	<3[b]	16.9[a]	8.2[a]
SE	<60[b]	<3[b]	-	-
SW	<60[b]	<3[b]	-	-
UWA	<5[b]	<3[b]	>20[b]	<3[b]
UWB	<60[b]	<3[b]	<3[b]	<3[b]

[a] estimated using logistic regression
[b] visually estimated
[c] transects impacted by runoff exposure

I. Materials and Methods
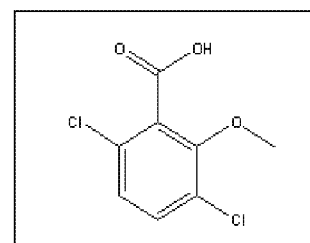
A. Materials

1. Test Material   Product Name: MON 76980 (Appendix B, pp. 94-95) - dicamba
Formulation Type: Liquid
CAS #: 104040-79-1
Lot Number: 11495284
Storage stability: The expiration date of the test substance was May 10, 2020.

Product Name: MON 79789 – glyphosate, potassium salt
Formulation type: Liquid
CAS Number: 70901-12-1
Lot Number: 11495283

Storage stability: The expiration date of the test substance was
May 7, 2020.

Product Name: Intact (polyethylene glycol, choline chloride, guar
gum)
Formulation type: Liquid
Lot Number: Not specified
Storage stability: The expiration date of the test substance was
May 14, 2020.

Product Name: MON 51817 (Potassium acetate)
Formulation type: Liquid
Lot Number: 390116
Storage stability: The expiration date of the test substance was
May 14, 2020.

2. Storage Conditions

The test substance and tank mix partners were received at the Lange Research and Consulting
facility on May 14, 2019 and stored at the test site in Shattuc, Illinois at ambient temperatures
ranging from 51.8 to 97.5 °F. It was not reported when the materials were shipped to the
application site. The test substance was sprayed on the test plot on July 2, 2019 (Appendix B, p.
96).

B. Study Design

1. Site Description

The test site was located in Clinton County in Shattuc, Illinois (Appendix B, pp. 97-98). A single
soybean-cropped field, measuring *ca.* 960 ft × 970 ft (293 m × 296 m, ~ 21 A) was treated with a
mixture of MON 76980 (containing dicamba), MON 79789 (containing glyphosate potassium
salt), Intact[TM] (polyethylene glycol, choline chloride, and guar gum), and potassium acetate. The
crop on the plot was a dicamba-tolerant soybean crop (Variety: Asgrow AG41X8) with a 300-ft
buffer surrounding the plot planted in non-tolerant soybeans (Variety: Dyna-Gro S40GL59). Soil
characterization indicated the USDA textural class was silt loam (Appendix B, p. 114). Prior to
the study, dicamba as Xtendimax was applied to the test plot in 2017. Crop history for the three
years preceding the study indicated the field had been planted in corn and soybean (Appendix B,
pp. 136). Terrain was flat with a slope less than 1%. The test plot was surrounded primarily by
agricultural land (Appendix B, Figure 3, p. 123). The soybean seeds were planted on June 3,
2019 at a density of 165,000 seeds/A on 20-inch row spacing for both plantings.

2. Application Details

Application rate(s):   The target application rate was 0.5 lb a.e./A or 15 GPA (p. 14, 18).
                                    The target application rate for the MON 51817 was 1.5 lb
                                    product/A (0.75 lb potassium acetate/A). Four application

monitoring samples consisting of four filter paper samples (Whatman #3, 12.5 cm diameter) each were positioned in the spray area in locations to capture various portions of the spray boom (Appendix B, p. 103).

The actual application rate calculated by using the application pass times and pass lengths and comparing those to a target pass time. The application was 103% of the target application rate (Appendix B, Table 6, p. 119).

Irrigation and Water Seal(s): No irrigation or water seals were reported in the study. Precipitation (2.35 inches) occurred during the vapor phase sampling portion of the study (pp. 13). Totals of 0.07, 2.01, 0.13 and 0.14 inches of rain fall was recorded during the 0-6, 36-48, 84-96, and 96-108 hour sampling events respectively (Appendix A, pp. 109).

Tarp Applications: Tarps were not used on the test plot. Tarps were used on nine plant effects transects before application, during application, and for at least 30 minutes following application to prevent exposure to spray drift to assess secondary movement only (pp. 572).

Application Equipment: A self-propelled John Deere R4038 sprayer equipped with a 120 ft boom was used for the spray application (Appendix B, p. 98). 96 Turbo TeeJet® Induction nozzles (TTI 11004) were installed with 15-inch spacing and the boom height was set at 20 inches above the crop canopy (15 cm, 6 in). The sprayer had one spray tank with a volume of 1,000 gallons.

Equipment Calibration Procedures: Nozzle uniformity was tested by spraying water at a pressure of 63 psi through the boom and measuring nozzle output using SpotOn® Model SC-1 sprayer calibrator devices (Appendix B, p. 98). Each nozzle was tested three times to determine variability. Calibration of the sprayer and nozzles established the total boom output per minute of spray to be 49.3 gallons/minute (GPM). A target spray rate of 15.0 GPA was achieved using the measured volume per minute output of the boom at 63 psi and a target speed of 13.6 mph (Appendix B, pp. 98)

Application Regime: The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated (acres)	Calculated Application Rate[2] (lb ae/acre)	Reported Application Rate[2] (gal/acre)
Soybean	Spray	7/2/2019 at 9:35 am	10.8	21	0.514	15.4

Data obtained from Appendix B, p. 93 and Appendix B, Table 1, p. 109 of the study report.
[1] Reviewer calculated as calculated application rate (lb a.e./acre) × area treated (acres).
[2] Reviewer calculated as percent of target applied (102.7%) × target application rate (0.5 lb a.e./acre, Appendix B, p. 119).

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3.**

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period[2]
Soybean	21	7/2/2019 between 9:35-9:49	7/2/2019 between 10:03-15:28	Not Applicable	7/2/2019 between 8:58-10:38

Data obtained from Appendix B, p. 93; Appendix B, Table 2, p. 110; and Appendix B, Table 5, p. 113 of the study report.
[1] Initial air monitoring period is that for perimeter stations. The initial period at the center station was 7/2/2019 between 10:10 – 15:29.
[2] Tarps were placed on select transects to evaluate volatility exposure without spray drift. The protocol was to remove the tarp 30 minutes after application, however some of the tarps were probably on the field for approximately 49 minutes.

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 6.8 (Appendix B, Table 1, p. 114). Soil measurements were collected via the 10-m Main Meteorological Station but were not provided in the report. Approximately 87% of the field was classified as a Cisne-Huey silt loam.

Table 4. Summary of soil properties for the soybean plot

Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm³)	Soil Composition
Soybean	0-6	Silt Loam	Cisne-Huey silt loam	Not Reported	1.14	% Organic Carbon[1] = 1.05% % Sand = 13% % Silt = 66% % Clay = 21%

Data obtained from Appendix B, pp. 95, 104, and Appendix B, Table 3, p. 111 of the study report.
[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72. Organic matter was reported as 1.8%.

4. Source Water

Tank mix water was obtained on June 30, 2019 (source of water not provided). The field pH of the source water was 8.17. The pH of the tank mix water was 7.8 with a hardness of 119 mg $CaCO_3$/L and a conductivity of 0.33 mmhos/cm (Appendix B, pp. 115).

5. Meteorological Sampling

Five meteorological stations were used to collect weather data during the study (Appendix B, p. 100).

The 10-meter main meteorological station was located upwind of the test plot (Appendix B, p. 100, and Figure 2, p. 122). The system included a Campbell CR1000X data logger and a Campbell Scientific 4G Cellular Modem to remotely monitor data. All parameters were reported at heights of 1.7, 5, and 10 m. The station included sensors for monitoring windspeed and direction (3D anemometer and 2D anemometers), air temperature, relative humidity, solar radiation, precipitation, soil temperature, and soil moisture.

A boom height anemometer collected wind speed and wind direction data during application at a nominal height 20 inches above the crop canopy (Appendix B, p. 100). The anemometer was located *ca.* 3 m upwind of the sprayed area.

The long duration main meteorological station was located upwind of the test plot and recorded data for 28 days post-test substance application (Appendix B, p. 101). The station included one Campbell Scientific ClimaVUE sensor which measured wind speed and direction, precipitation, and barometric pressure at 1 m and soil moisture and temperature sensors.

The primary flux meteorological station was deployed outside of the plot prior to application and was then moved to the center of the plot, remaining there until after the final drift sample was collected on the morning of July 9, 2019 (Appendix B, p. 101). The station included a Campbell CR1000X data logger and a Campbell Scientific 4G Cellular Modem to remotely monitor data. The station included sensors for air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy.

A secondary flux meteorological station was positioned upwind and outside of the sprayed area. A secondary flux meteorological station also recorded air temperature, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy (Appendix B, p. 101).

Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 5. Summary of meteorological parameters measured in the field

Field	Parameter	Monitoring heights (m)	Averaging Period
Soybean Plot 10-Meter Main Met. Station	Air temperature	1.7, 5, and 10	1 minute
	Relative humidity	1.7, 5, and 10	1 minute
	Wind speed/wind direction	1.7, 5, and 10	1 minute

Field	Parameter	Monitoring heights (m)	Averaging Period
Soybean Plot Boom Height Anemometer	Wind speed/wind direction	0.65	Not reported
Soybean Plot Long Duration Main Met. Station	Precipitation	1.0	Not reported
	Air temperature	1.0	Not reported
	Relative humidity	1.0	Not reported
	Soil temperature	Not specified	Not reported
	Soil moisture	Not specified	Not reported
	Solar radiation	1.0	Not reported
	Wind speed/wind direction	1.0	Not reported
Soybean Plot Primary Flux Met. Station	Air temperature	0.33, 0.55, 0.9, and 1.5[1]	1 minute[2]
	Relative humidity	0.33, 0.55, 0.9, and 1.5[1]	1 minute[2]
	Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5[1]	1 minute[2]
Soybean Plot Secondary Flux Met. Station	Air temperature	0.33, 0.55, 0.9, and 1.5[1]	1 minute[2]
	Relative humidity	0.33, 0.55, 0.9, and 1.5[1]	1 minute[2]
	Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5[1]	1 minute[2]

Data obtained from pp. 18 and Appendix B, pp. 100-101 of the study report.
1. Denotes height above crop canopy
2. Spreadsheet files submitted with study report indicate meteorological data from flux met stations were collected every minute.

6. Air Sampling

Two pre-application samples were collected at 0.15 m above the crop canopy at the approximate center of the test plot (Appendix B, pp. 104). Samples were collected for *ca.* 6 hours on June 30, 2019 from 11:14 to 17:17.

Post-application in-field air samplers were used for flux monitoring for *ca.* 168 hours following application (Appendix B, p. 104). Samplers were placed on a mast in the approximate center of the plot directly following spray application at heights of 0.15, 0.33, 0.55, 0.90, and two at 1.5 m above the crop surface. Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The 0 to 6-hour and 6 to 12-hour samples were pro-rated based on the time remaining until sunset on the day of application, with subsequent samples being collected on a sunrise-sunset schedule.

Off the plot, eight perimeter air monitoring stations were located 1.5 m above the crop canopy and 5 m outside the edge of the plot (Appendix B, p. 105). Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sampling schedule was the same as for the in-field air sampling. The 0 to 6-hour and 6 to 12-hour samples were pro-rated based on the time remaining until sunset on the day of application, with subsequent samples being collected on a sunrise-sunset schedule.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects, two left wind transects, two right wind transects, and two upwind transects (Appendix B, pp. 105). Samples were also collected with a control plot, upwind of the spray area. All transects were perpendicular to the

edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 90 m in all three of the downwind transects and one left wind transect. Deposition collectors were secured to carboard squares and attached to a horizontal plastic platform at crop height. Initial deposition samples were collected 22 minutes after spray application was completed. Initial downwind deposition sample collection times ranged from 22 to 59 minutes after the start of application (Appendix B, pp. 151). Deposition samples were collected at intervals of 1, 24, 48, 72, 96, 120, 144, and 168 hours post-application.

A total of 47 deposition filter paper samples were unable to be collected from the 96, 120, and 168-hour collection periods due to rainfall. Study authors indicate that samples from earlier periods of collection, where higher concentrations are expected to occur, resulted in levels of detection that were too low to be used for deposition modeling. As a result, study authors concluded that these later uncollected samples would also contain levels of residue too low for modeling and is not expected to have a negative effect on the study.

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to dicamba tolerant soybeans was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the treated soybean field and perpendicular to the sprayed field edges of the application area, as well as four transects radiating from the corners of the sprayed field out to a maximum distance of approximately 90 meters (Appendix G, pp. 572; Figure 1, p. 582). Height effects and visual symptomology were recorded at 0, 14, and 28 ($\pm$ 2) days after spray application of the tank mix. Dicamba-non-tolerant soybean were evaluated at distances of approximately 3, 5, 10, 20, and 60 meters from the edge of the treatment application field on the upwind, right wind, left wind, southwest, and southeast transects, with the downwind and northwest and northeast transects extended out to 90 meters, with additional samples collected at 40 and 50 meters. Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, four upwind control areas were identified and evaluated for plant height.

Plant effects from volatility only were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (volatility covers) during the application period to prevent exposure to spray drift (Appendix G, pp. 572; Figure 1, pp. 582, and 4, pp. 584). The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology resulting from volatilization of dicamba. The plastic covers were intended to remain in place for approximately 30 min post-application before permanent removal for the remainder of the study. The actual time the plants remained covered ranged from 8:58 am to 10:38 pm (approximately 1.67 hrs. total and approximately 49 mins post-application). Transects for volatility only were 20 m long and plant height measurements and visual symptomology ratings were completed at approximately 3, 5, 10, and 20 m from the sprayed area at 0, 14, and 28 days after treatment (Appendix G, pp. 626).

At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points. Plant height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud to the nearest centimeter using a metal metric ruler. Where multiple shoots were present, measurements along the main shoot were taken.

9.   Sample Handling and Storage Stability

PUF sorbent tube and deposition filter paper samples were handled with nitrile gloves, which were replaced after the collection of samples and prior to installation of a new sample media for the next sampling interval (Appendix B, p. 102). PUF sorbent tubes and filter papers were placed in pre-labeled conical tubes and transferred to a freezer/cooler or stored in an ambient container for storage prior to shipment. Pre-application, application monitoring, field exposed spikes, transit stability PUF were stored in a freezer prior to shipment. Pre-application and application monitoring samples were stored in separate freezers from post-application, field spike, and transit stability samples. Samples were shipped in ice chests containing dry ice to either the Eurofins or Monsanto laboratories. Tank mix samples were stored and shipped in a cooler under ambient conditions. Soil and water samples were shipped cool on blue ice via Fedex to AGVISE Laboratories.

All field collected PUF and filter paper samples were extracted within 13 and 31 days, respectively, after collection (Appendix C, p. 263-268, Appendix D, pp. 418-429). All field exposed QC and transit stability samples were extracted within 15 days after fortification. Stability of dicamba on PUF and filter paper samples was demonstrated for at least 78 and 85 days, respectively, during frozen storage in a stability study (Maher 2016). All PUF and filter paper samples were analyzed within 2 and 7 days, respectively, after extraction, which study authors indicate is within the demonstrated stability (Appendix C, p. 263-268, Appendix D, pp. 418-429).

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of PUF collectors and tubing protected from precipitation by ¾ inch diameter PVC pipes (Appendix B, p. 104). SKC air sampling pumps were used, covered with plastic bags to protect them from precipitation. Pumps were calibrated to a target flow rate of 3.0 L/min. Spray drift deposition collectors consisted of Whatman #1 15 cm diameter filter papers.

- Extraction method: The contents of the PUF sorbent tubes were extracted using methanol containing stable-labeled internal standard per the current version of analytical method ME-2242 (Appendix C, pp. 166). The sample was fortified with internal standard, two grinding balls were added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 30 minutes. The cap was removed, and a 1.5 mL aliquot was transferred to a 0.45 μm polypropylene 96-well filter plate with a clean polypropylene plate positioned below the filter plate (Appendix C, pp. 328-329). The sample was evaporated to dryness under nitrogen at 50°C. The sample was reconstituted with 0.100 mL of 25% methanol in water. The sample

was mixed and analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 214-215).

The filter paper samples were extracted using methanol containing stable-labelled internal standard (Appendix C, pp. 332). The sample was fortified with internal standard, a grinding ball was added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 5 minutes. The tubes were then placed in a ≤10°C centrifuge (4500 xg for 5 minutes) and spun to clear suspended materials from the liquid column and form a solid pellet. The cap was removed and a 0.35 mL aliquot was transferred to a clean 96-well filter plate with a clean, glass-lined polypropylene plate positioned below the filter plate (Appendix C, pp. 339). The plates were then placed in a ≤10°C centrifuge (1500 xg for 1 minute) and spun until liquid passed through the plate. The solution was analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 332).

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying 15 replicate fortification samples at each of three fortification levels (0.1 ng/PUF, 6 ng/PUF, and 60 ng/PUF; Appendix C, pp. 322-326). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions except for one sample at 0.1 ng/PUF which had a recovery of 128%. Average recoveries were 103%, 99%, and 9% at 0.13, 6, and 60 ng/PUF, respectively. No independent laboratory validation was provided. The LOQ during method validation was 0.10 ng/PUF. An LOD was not provided in the study report, however a value of 0.03 ng/PUF was reported in the flux estimation spreadsheet.

  Method validation was achieved by fortifying 30 replicate fortification samples at each of three fortification levels (0.005, 0.10, and 4.8 µg/filter paper; Appendix D, pp. 330). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level. Average recoveries were 105%, 106%, and 103% at 0.005, 0.10, and 4.8 µg/filter paper, respectively. No independent laboratory validation was provided. The LOQ during method validation was 0.005 µg/filter paper; an LOD was not provided (Appendix C, p. 326).

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.03 to 7.5 ng/PUF (Appendix C, p. 212). Concentrations were 0.03, 0.075, 0.1, 0.15, 0.3, 0.75, 1.0, 1.5, 3.0, and 7.5 ng/PUF. Analyst® software was used to derive the calibration curve using a weighted linear curve (1/x; Appendix C, pp. 250).

  Calibration standards were prepared at concentrations ranging from 0.0015 to 6 µg/filter paper (Appendix D, p. 326). Concentrations were 0.0015, 0.003, 0.0075, 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, and 6 µg/filter paper. Analyst® software was used to derive the calibration curve using a weighted linear curve ($1/x^2$; Appendix D, pp. 383).

11. Quality Control for Air Sampling

Lab Recovery: 26 of 33 laboratory spike recoveries are within the acceptable range of
90-110% (Appendix C, pp. 372-373). All laboratory spike recoveries are
within the range of 78-128%. Laboratory spike samples were prepared at
fortification levels of 0.1 ng/PUF (15 samples), 6 ng/PUF (15 samples),
and 60 ng/PUF (3 samples). Average recoveries were 103%, 99% and
98% at 0.1 ng/PUF, 6 ng/PUF, and 60 ng/PUF, respectively (Appendix C,
p. 249).

Field blanks: Two pre-application samples were collected from the center of the test
plot from 11:14 to 17:17 on June 30, 2019, the day before application
(Appendix B, pp. 104). Dicamba was below the LOQ in both pre-
application samples (Appendix C, pp. 252).

One of six control samples from field spike analyses contained dicamba
above the LOQ (0.12 ng/PUF); the remaining 5 samples were below the
LOQ (Appendix C, p. 260-261).

Field Recovery: Nine 6-hour and nine 12-hour field spike samples were collected at
concentration levels of 3, 10, and 30 ng/PUF. A total of six field spikes
were prepared at each concentration level. All field spike recoveries are
within the acceptable range with overall recoveries of 94% to 107% at 3
ng/PUF, 89% to 104% at 10 ng/PUF, and 94% to 109% at 30 ng/PUF
(Appendix C, p. 260-261).

Travel Recovery: Three transit stability PUF samples were fortified at 30 ng/PUF and
placed on dry ice along with three unfortified control samples (Appendix
C, p. 261). Dicamba was not detected in the control samples. The range
of recoveries from the fortified samples was from 92% to 106%.

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries
ranging from 96% to 101% (Appendix C, pp. 249). The highest dicamba
amount measured on a PUF sample (excluding laboratory and field
spikes) was 8.34 ng/PUF (Appendix C, pp. 252-260) which is *ca.* 14% of
the highest fortification level, indicating that dicamba loss due to
breakthrough is unlikely.

12. Quality Control for Deposition Sampling

Lab Recovery: 79 of 90 laboratory spike recoveries are within the acceptable range of
90-110% (Appendix D, pp. 381-381). All laboratory spike recoveries are
within the range of 86-113%. Laboratory spike samples were prepared at
fortification levels of 0.005 µg/filter (30 samples), 0.1 µg/filter (30
samples), and 4.8 µg/filter (30 samples). Average recoveries were 105%,

106%, and 103% at 0.005 µg/filter, 0.1 µg/filter, and 4.8 µg/filter, respectively (Appendix D, p. 382).

Travel Recovery: Five transit stability filter paper samples were fortified at 0.05 µg/filter paper and placed on dry ice along with five unfortified control samples (Appendix C, p. 408-409). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 105% to 110%.

13. Application Verification

Four application monitoring sampling stations, each consisting of four 12.5 cm diameter Whatman #3 filter paper samples, were positioned in the spray area at the crop height, or 15 cm (Appendix B, p. 103). The stations were positioned to capture different portions of the spray boom and different spray nozzles. The average recovery relative to the target was 92%, with a range of 74-106% of the target rate (Appendix B, Table 2, p. 172).

The spray application was made with a target rate of 15.0 GPA and a target sprayer speed of 13.6 mph. The application verification was calculated from the recorded pass times, with the actual application rate calculated as 103% of the target rate (Appendix B, Table 6, p. 119).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix C, pp. 167). The average weight percent was 0.381% for pre-application samples and 0.38% for post-application samples, with the theoretical tank mix concentration of 0.40% dicamba.

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated based on the calculated flux rates and relevant meteorological data. Study authors used U.S. EPA's AERMOD model (version 19191) to estimate deposition and the Probabilistic Exposure and Risk model for Fumigants (PERFUM2, version 2.5) to estimate air concentrations (Appendix F, p. 529-530). Three sets of estimates were calculated, using meteorological data for Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas (Appendix F, p. 534). The reviewer used PERFUM version 3.2 to estimate air concentrations using the same meteorological data.

The maximum flux predicted by any method for each period was chosen to represent that period. The reviewer followed the same method but mapped the periods onto hours of the day (1- 24) and the maximum flux rate for each hour was then chosen to represent that hour, regardless of the day from which it was collected. In cases where two periods occurred in a single hour, a weighted average of the flux rates was used. The 24-hour flux profile for the first two days were used as inputs for PERFUM2 and as adjustment factors for input into AERMOD. The reviewer and study author flux rates were slightly different, particularly where weighted averaging occurred. However, they did not impact the overall modeling conclusions.

Wet and dry deposition estimates were made at 10 distances from the field (5, 10, 20, 30, 40, 50, 75, 100, 125, and 150 m; Appendix E, pp. 536). Dry deposition was typically an order of magnitude higher than wet deposition. For the fluxes from the soybean plot at a distance of 5 m from the edge of the field, maximum 24-hour average dry deposition ranged from 0.86 to 1.47 $\mu g/m^2$ (Appendix F, Table 8, pp. 536). 90th percentile dry deposition ranged from 0.47 to 0.75 $\mu g/m^2$.

Modeled dicamba air concentrations were calculated at 4 distances from the field (5, 10, 25, and 50 m; Appendix F, pp. 539). Modeled 95th percentile 24-hr air concentrations ranged from 1.9 to 2.8 ng/m^3 at 5 m from the edge of the treated field and 1.3 to 1.9 ng/m^3 at 50 m from the edge of the field.

The reviewer estimated total deposition and air concentrations based on the estimated flux rates and arrived at similar estimates. The maximum 24-hour average total deposition ranged from 1.21 to 1.59 $\mu g/m2$ and 90th percentile total deposition ranged from 0.73 to 0.95 $\mu g/m^2$. Modeled 95th percentile 24-hr air concentrations ranged from 3.9 to 6.3 ng/m^3 at 5 m from the edge of the treated field. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Modeled 24-hour air concentrations were slightly higher (5.7-12 ng/m^3), but comparable, than those achieved for the North Carolina, Illinois, and Texas modeling results. The difference in the study authors and reviewer results is a function of the differences in the flux rates used in the modeling.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 19191) and a unit flux rate of 0.001 $g/m^2\cdot s$ to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. Study authors initially regressed the data with an intercept through the origin. If the slope of the linear regression did not result in a statistically significant relationship, study authors removed the spatial relationship by sorting both the measured and modeled air concentrations (independently) in ascending order, then redoing the regression, with the final flux estimate calculated as the slope of this alternative regression multiplied by the nominal flux.

Aerodynamic Method

The aerodynamic method, also referred to as the "flux-gradient" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

$$\text{Equation 1} \qquad P = \frac{k^2 (\Delta \bar{c})(\Delta \bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman's constant (dimensionless ~0.4), $\Delta \bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta \bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

$$\text{Equation 2} \qquad Flux = \frac{-(0.42)^2 (c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL) stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

$$\text{Equation 3} \qquad R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\dfrac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + \left(u_{ztop} - u_{zbottom}\right)^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$$\phi_m = \left(1 + 16R_i\right)^{0.33} \ and \ \phi_p = 0.885(1 + 34R_i)^{0.4}$$

if $R_i < 0$ (for Convective/Unstable IBL)
$$\phi_m = \left(1 - 16R_i\right)^{-0.33} \ and \ \phi_p = 0.885(1 - 22R_i)^{-0.4}$$

The minimum fetch requirement that the fetch is 100 times the highest height of the air sampler for this method to be valid was not satisfied at all times. Given the highest height sampled was 1.65 m (1.5 m above the crop which was 15 cm), the minimum fetch distance is 165 m. Based on wind direction analysis, this requirement was satisfied for 8 of the 15 sampling periods. If the minimum fetch were considered 150 m, the height of the highest sampler above the crop, then the minimum fetch distance would have been satisfied for all sampling periods. As such, there is some uncertainty in the flux rates derived from this analysis, as the internal boundary layer depth may not have been sufficient. The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

$$\text{Equation 4} \qquad P = \frac{1}{x} \int_{Z_0}^{Z_p} \overline{c}\,\overline{u}\, dz$$

where P is the volatile flux in units of $\mu g/m^2 \cdot s$, $\overline{c}$ is the average pesticide residue concentration in units of $\mu g/m^3$ at height Z in units of meters, $\overline{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters,

and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 4 is simplified as follows in equation 5 (Yates, 1996):

$$\text{Equation 5} \qquad P = \frac{1}{x} \sum_{Z_0}^{Z_p} (A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

$$\text{Equation 6} \qquad Z_P = \exp\left[\frac{(0.1 - D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface characteristics of the field consisted of soybeans at 6 inches (15 cm) in height. For all sampling periods, the surface roughness length was equal to or less than 0.045 m, below the required of 0.1 meters for this method to be valid.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 5.2 prior to application.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Notes	Registrant ($\mu g/m^2 \cdot s$)	Notes
1	7/2/19 10:00 – 15:00	5:00	0.000547	Regression, no intercept	0.000300	A
2	7/2/19 15:00 – 18:00	3:00	0.000035	Regression	0.000086	A
3	7/2/19-7/3/19 18:00 – 8:00	14:00	0.000064	Regression	0.000043	A
4	7/3/19 8:00 – 17:00	9:00	0.000084	Regression	0.000077	A
5	7/3/19-7/4/19 17:00 – 8:00	15:00	0.000141	Ratio of averages	0.000068	B
6	7/4/19 8:00 – 18:00	10:00	0.000148	Regression	0.000082	A
7	7/4/19-7/5/19 18:00 – 8:00	14:00	0.000059	Regression, no intercept	0.000026	A
8	7/5/19 8:00 – 17:00	9:00	0.000018	Regression	0.000043	A

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Notes	Registrant ($\mu g/m^2 \cdot s$)	Notes
9	7/5/19-7/6/19 17:00 – 8:00	15:00	0.000005	Regression, no intercept	0.000003	B
10	7/6/19 8:00 – 18:00	10:00	0.000023	Regression, no intercept	0.000020	A
11	7/6/19-7/7/19 18:00 – 8:00	14:00	0.000011	Regression, no intercept	0.000014	B
12	7/7/19 8:00 – 18:00	10:00	0.000037	Regression, no intercept	0.000034	B
13	7/7/19-7/8/19 18:00 – 8:00	14:00	0.000015	Regression, no intercept	0.000014	B
14	7/8/19 8:00 – 18:00	10:00	0.000036	Regression, no intercept	0.000027	B
15	7/8/19-7/9/19 18:00 – 8:00	14:00	0.000018	Regression, no intercept	0.000025	B

Data obtained from Appendix F, Table 3, pp. 511 of the study report.
Notes
A   Linear regression with the intercept set to zero was used to calculate the flux for the sampling period.
B   The spatial regression method was used to calculate the flux for the sampling period.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Registrant ($\mu g/m^2 \cdot s$)	Empirical Flux Determination Method[*]	Notes
1	7/2/19 10:10 – 15:29	5:19	0.000139 0.000679	0.000139 0.000679	IHF AD	
2	7/2/19 15:33 – 18:04	2:31	0.000036 0.000093	0.000036 0.000093	IHF AD	
3	7/2/19-7/3/19 18:09 – 7:54	13:45	0.000027 0.000016	0.000027 0.000016	IHF AD	
4	7/3/19 7:58 – 16:45	8:47	0.000020 0.000062	0.000020 0.000062	IHF AD	
5	7/3/19-7/4/19 16:51 – 7:46	14:55	0.000008 0.000019	0.000008 0.000019	IHF AD	
6	7/4/19 7:50 – 17:34	9:44	0.000099 0.000002	0.000027 0.000002	IHF AD	
7	7/4/19-7/5/19 17:38 – 7:46	14:08	0.000018 0.000003	0.000013 0.000003	IHF AD	
8	7/5/19 7:48 – 16:34	8:46	0.000014 0.000006	0.000014 0.000006	IHF AD	
9	7/5/19-7/6/19 16:37 – 8:01	15:24	0.000001 0.000016	0.000001 0.000016	IHF AD	

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Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			Notes
			Reviewer ($\mu g/m^2 \cdot s$)	Registrant ($\mu g/m^2 \cdot s$)	Empirical Flux Determination Method*	
10	7/6/19 8:04 – 18:09	10:05	0.000003 0.000039	0.000003 0.000039	IHF AD	
11	7/6/19-7/7/19 18:12 – 7:42	13:30	0.000019 0.000000	0.000004 0.000000	IHF AD	
12	7/7/19 7:45 – 18:13	10:28	0.000055 0.000004	0.000015 0.000004	IHF AD	
13	7/7/19-7/8/19 18:00 – 8:00	14:00	NC	NC	IHF AD	A
14	7/8/19 8:00 – 18:00	10:00	NC	NC	IHF AD	A
15	7/8/19-7/9/19 18:00 – 8:00	14:00	NC	NC	IHF AD	A

Data obtained from Appendix B, Table 5, pp. 113-114; Appendix D, Table 8, p. 555; and Appendix D, Table 10, p. 558 of the study report.
NC indicates not calculated.
*Methods legend: AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.
Notes
A   Periods 13, 14, and 15 showed a reverse gradient of air concentrations against sample height, so flux rates were not calculated for these periods.

For the aerodynamic and integrated horizontal flux methods, measured concentrations for periods 13 through 15 exhibited a reverse gradient of air concentrations against sample height (i.e., air concentrations increased with height). As a result, flux rates for these periods were not estimated. It should be noted that all of the air concentrations measured during these periods were above the LOQ.

The maximum flux rate calculated by all three methods occurred during the initial sampling period after application. Maximum flux rates were 0.000547 $\mu g/m^2 \cdot s$, 0.000139 $\mu g/m^2 \cdot s$, and 0.000679 $\mu g/m^2 \cdot s$ for the indirect, integrated horizontal flux, and aerodynamic methods, respectively.

R-squared values for the linear regressions of modeled and measured air concentrations in the indirect method ranged from 0.20 to 0.90 for periods 1 through 4 and 6 through 15. The reviewer used the spatial regression method or the spatial regression using an intercept of zero to estimate flux for all periods except period 5 when a ratio of the average concentrations was used. Reviewer and study author flux rates were similar.

R-squared values in log-linear vertical profiles of wind speed were generally high with all R-squared values ≥ 0.95. R-squared values in log-linear vertical profiles of concentration were low for period 2 (0.541), Period 9 (0.576), Period 11 (0.005), and Period 12 (0.037). R-squared values in log-linear vertical profiles of temperature were variable and ranged from 0.27 for period 6 to 0.99 for period 3.

C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were detected at a maximum fraction of the applied deposition of 0.006928 at 3 m from the field within the first hour after application (Appendix D, Table 2, pp. 331-348). Dicamba residues were not detected in any of the upwind or right wind samples within the first hour after application. **Figures 4** and **5** depict the deposition fractions and the reviewer-predicted spray drift curves for the downwind and left wind transects within the first hour after application.

To develop the deposition curves, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

Study authors derived deposition curves using a four parameter, exponential decay model used to capture biphasic deposition for each transect (Appendix G, p. 547). The curves were similar to those generated by the reviewer.

Estimated distances from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) ranged from 8.3 to 12.3 m and 9.7 to 15.8 m in the downwind and left wind directions, respectively, using the reviewer-developed curves and ranged from 10 to 18.1 m in the downwind direction and 12.7 to 1.5 m in the left wind direction for the study author developed curves.

Figure 4   Spray Drift Analysis for Downwind Transects – 1 Hour
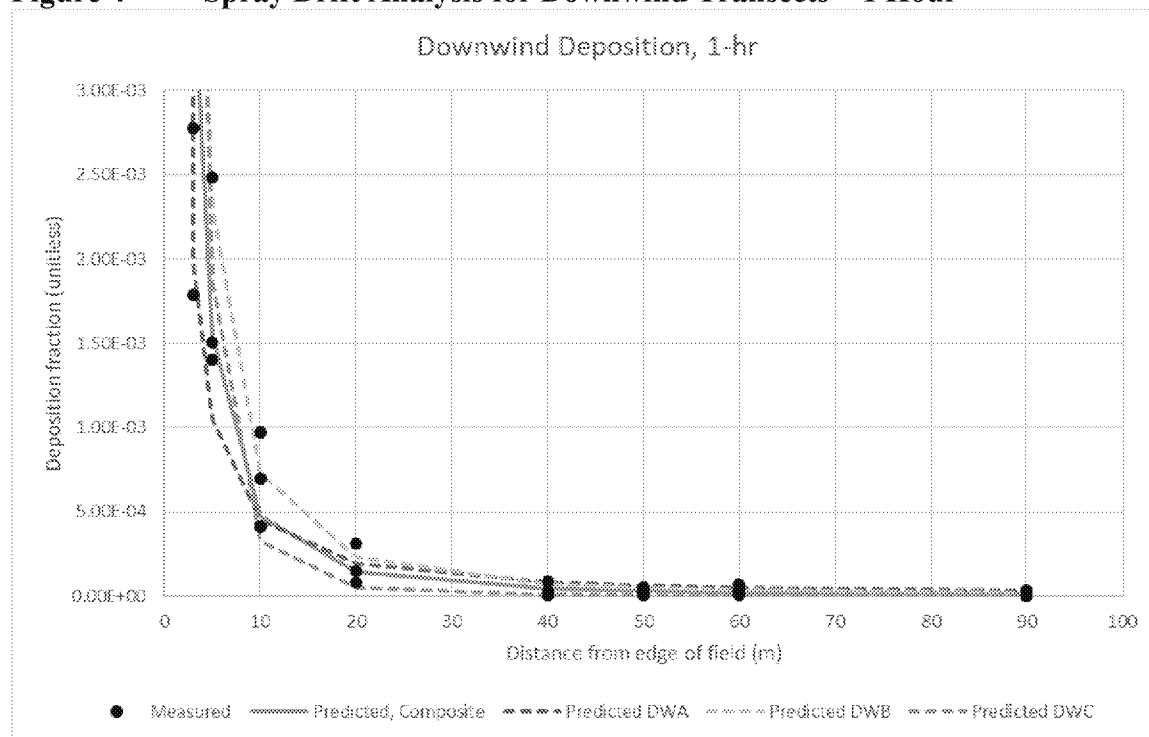
Figure 5   Spray Drift Analysis for Left wind Transects – 1 Hour
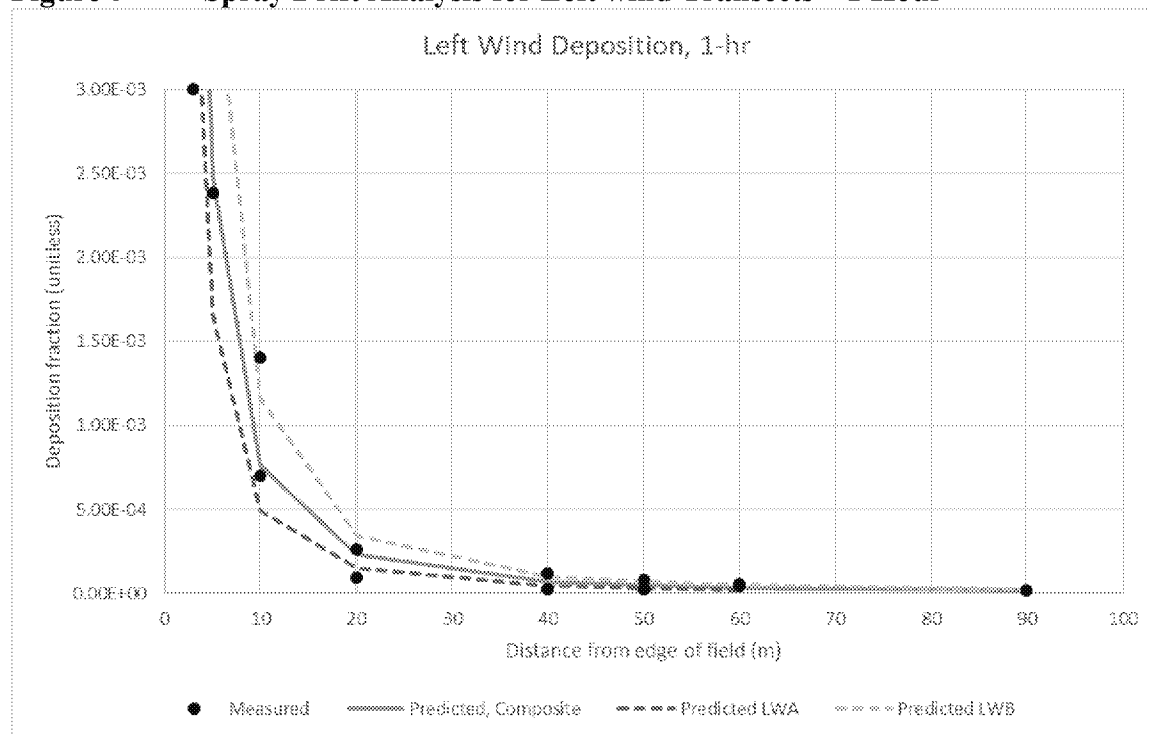
D. Plant Effects Results

Spray Drift + Volatility Exposure Transects

Plant Height

The reviewer found significant inhibitions of plant height along downwind (DW), left wind (LW) and east diagonal transects. The reviewer evaluated each of the observed transects independently using logistic regression methods in Excel (Figures 6, 8, 10, & 12). The best fit regression (as indicated by the R^2) for each transect were used to estimate the distance at which a 5% reduction in plant height would be predicted based on the comparison to the mean plant height from control plots. Table 6b provides the estimated distances to 5% reduction in plant height for each transect.

Flooding and runoff from the treated area was reported to have impacted a few of the transects. The impact of this on plant height effects is uncertain. The reviewer considered the reported impacts on individual transects and plots, and determined that the reduced plant height effects are attributed to the dicamba exposure during application, for those transects used to established distances in Table 6b. Notably, transects RWA, RWB and NE were determined to be principally impacted by runoff. VSI suggested that dicamba exposure had occurred in these same locations.

A major uncertainty in the implementation of this study was that the measurements of plant height were not consistently taken from the same individual plants over the course of the successive sampling events. While the study authors indicate that the initial plot distances were selected to reduce variability in plant height at the start of the study, it is unclear how the transects relate to the rest of the field, and more importantly how other plants in the plot were responding as compared to those that were selected "non-systematically" for measurement of plant height. No discussion was provided to explain how the plants were selected such to prevent selection of the healthiest looking plants from a plot. This uncertainty may contribute to underestimation of effects and therefore underestimation of off-field distance estimates.

Visual Signs of Injury (VSI)

Visible symptomology was reported, but the specific phytotoxic symptoms were not detailed for the transects. For the drift study, the same transects that showed a dose response relative to the field for the height endpoint, also showed a dose response for VSI (Table 8). For these transects, linear, logistic and polynomial regression methods in Excel to estimate the distance to the point where 10% VSI would be predicted (Figures 7, 9, & 11). The furthest distances to 10% VSI were consistent with the transects that showed significant effects on plant height although they do not go out as far as the height estimated distances (Table 6b).

Volatility Exposure (covered) Transects

Plant height measures and distances estimated with logistic regression, indicate that impacts to plant height were significantly less than observed along the uncovered transects. However, just as described for the uncovered transects, there was a lot of variability in plant height across the

field. Any signal of reduction relative to the controls is greatly impacted by this background variability. RWA and RWB transects were likely exposed to dicamba through runoff and were the only covered transects that reported significant VSI observation.

There are several concerns with the conduct and conditions of this study. In terms of the utility of the volatility transects (covered transects), a significant rain event (2 in) occurred between hours 36 and 48, reducing the emissions from volatility. This reduction impacts the amount of material that the transects may have been exposed to via volatilization. Distances based on vapor exposure alone (covered transects) will reflect plant responses to this lowered exposure and may underestimate distances under conditions of no rainfall.

Table 8. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

Exposure pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height	Distance to 10% VSI	Distance to 5% Height	Distance to 10% VSI
DWA	36.6[a]	<5[b]	16.9[a]	<3[b]
DWB	76.1[a]	<5[b]	>20[b]	<3[b]
DWC	37.3[a]	8.4[a]	<20[b]	<3[b]
LWA	>60[b]	13.4[a]	<10[b]	<3[b]
LWB	59.2[a]	11.1[a]	>20[b]	<3[b]
NE[c]	<40[b]	<40[b]	-	-
NW	35.9[a]	24.7[a]	-	-
RWA[c]	>60[b]	>50[b]	4.5[a]	22.6[a]
RWB[c]	<3[b]	<3[b]	16.9[a]	8.2[a]
SE	<60[b]	<3[b]	-	-
SW	<60[b]	<3[b]	-	-
UWA	<5[b]	<3[b]	>20[b]	<3[b]
UWB	<60[b]	<3[b]	<3[b]	<3[b]

[a] estimated using logistic regression
[b] visually estimated
[c] transects impacted by runoff exposure

Plant Height and Off-Field Distances at 28 DAT

$$y = 5.2764\ln(x) + 17.888$$
$$R^2 = 0.7971$$

$$y = 2.9594\ln(x) + 24.16$$
$$R^2 = 0.9089$$
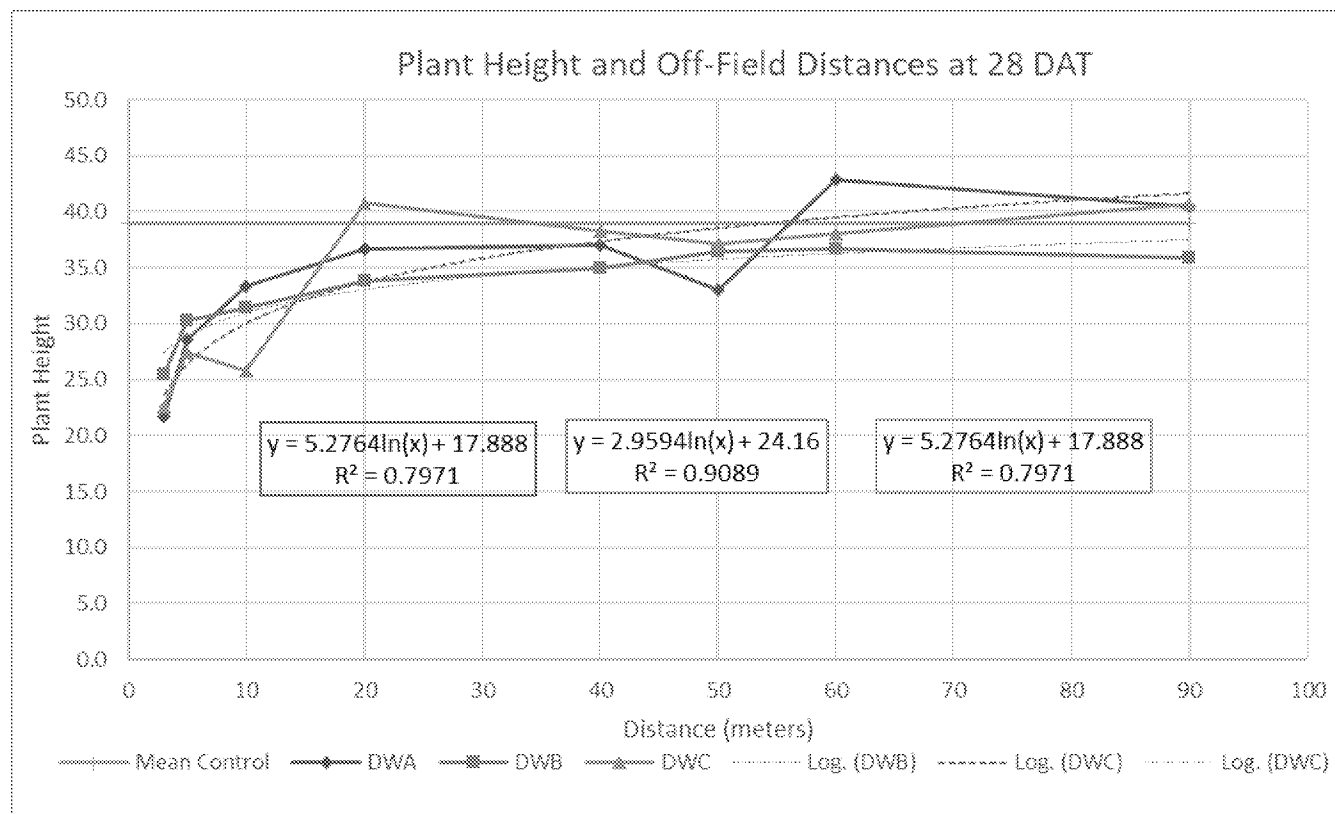
$$y = 5.2764\ln(x) + 17.888$$
$$R^2 = 0.7971$$

Figure 6: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".
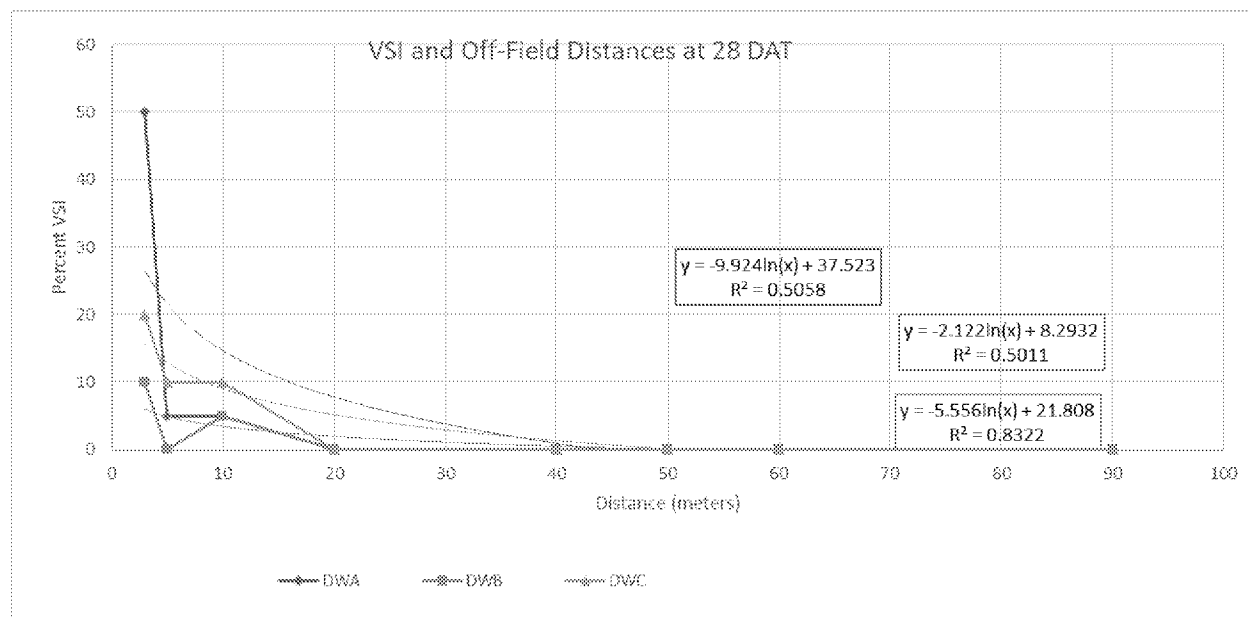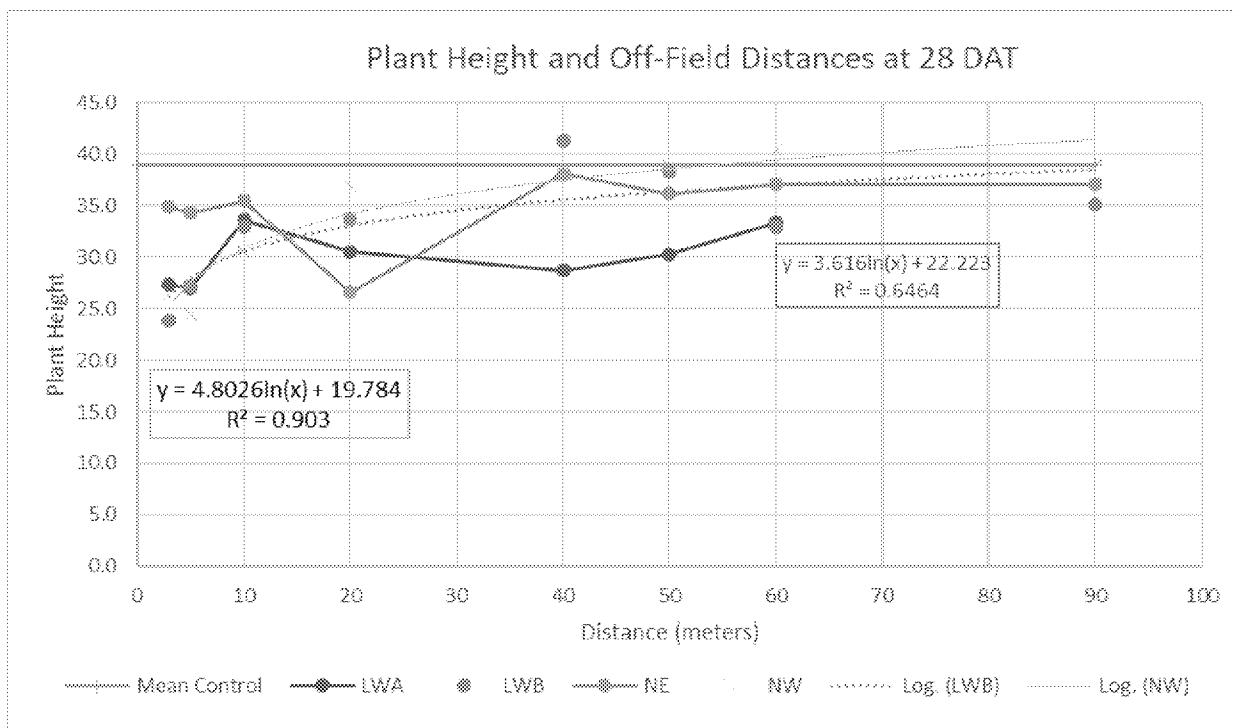
VSI and Off-Field Distances at 28 DAT

$$y = -9.924\ln(x) + 37.523$$
$$R^2 = 0.5058$$

$$y = -2.122\ln(x) + 8.2932$$
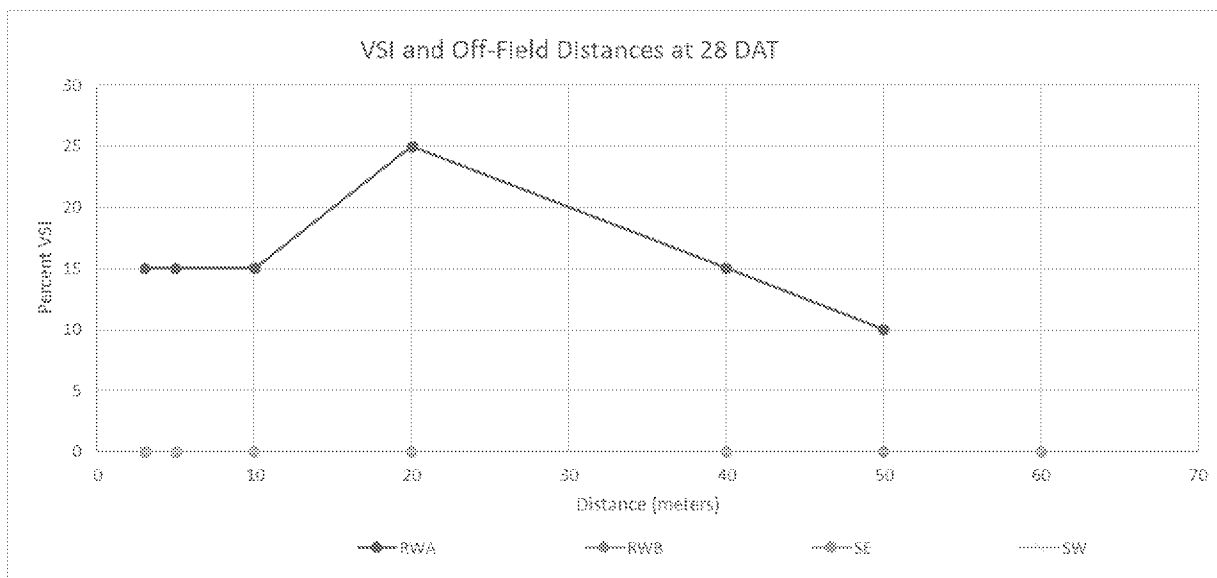$$R^2 = 0.5011$$

$$y = -5.556\ln(x) + 21.808$$
$$R^2 = 0.8322$$

Figure 7: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "DW" uncovered transects.

Figure 8: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind", "NE" and "NW" uncovered transects.
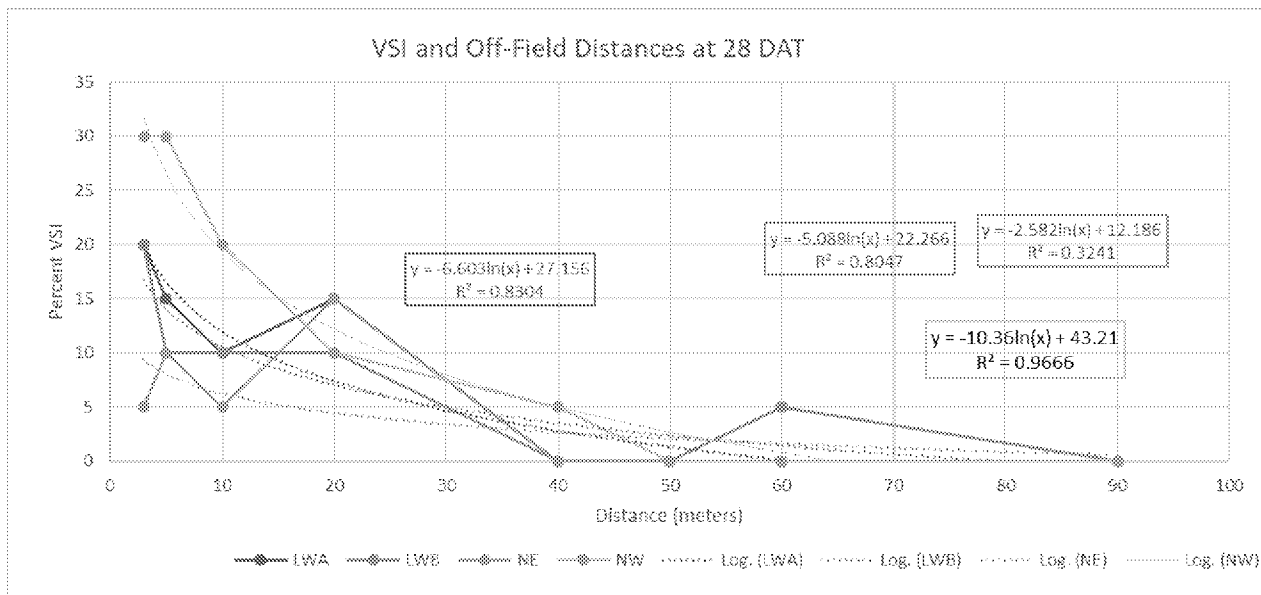
Figure 9: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "LW", "NE" and "NW" uncovered transects.

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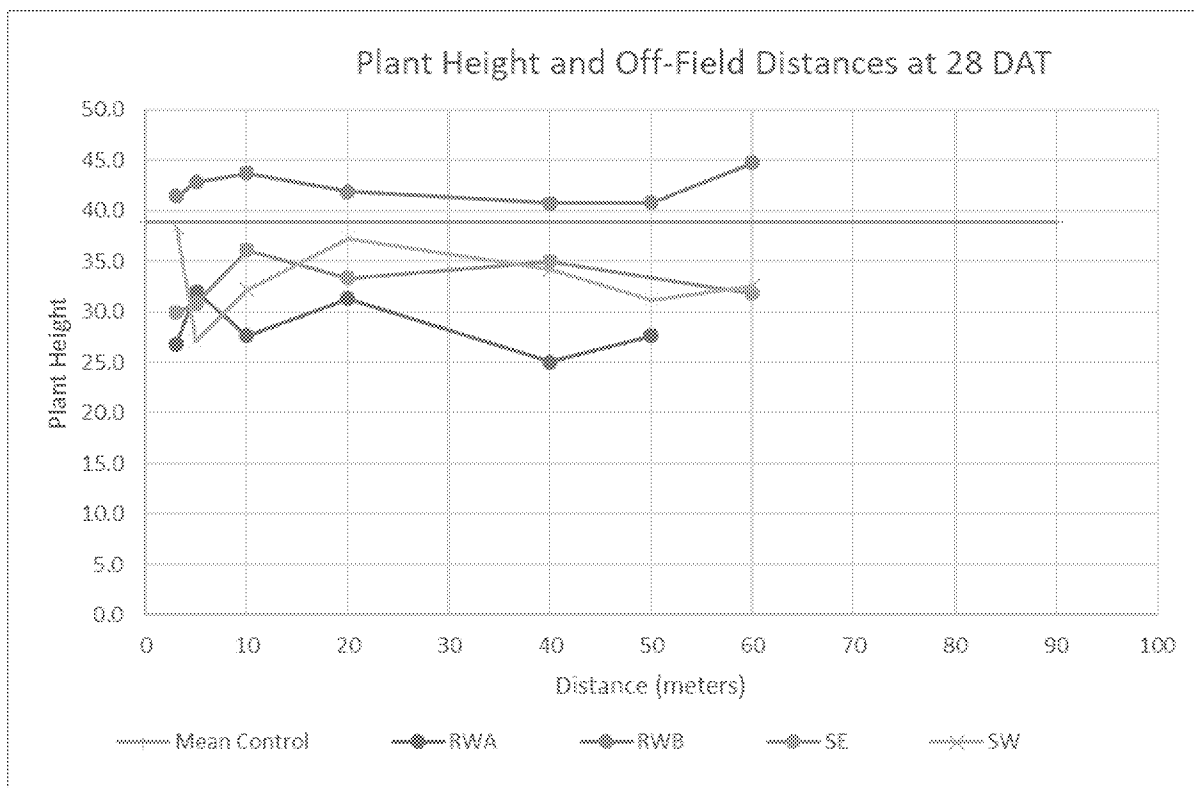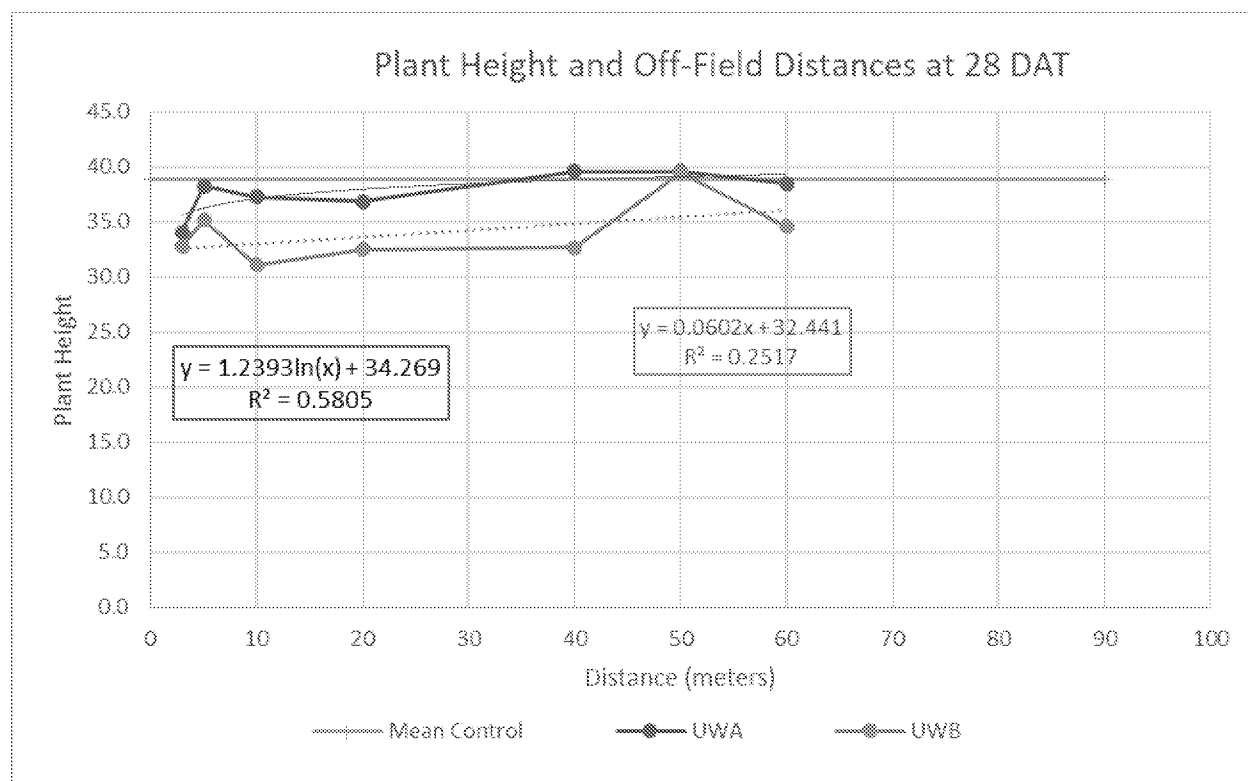
Figure 10: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "RW" "SE and "SW" uncovered transects. Note: transects showed no drift related effects on plant height and reflect the wide variation in plant height across the field.

Figure 11: VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for for "RW" "SE and "SW" uncovered transects. Note: transects showed no drift related effects on plant height and reflect the wide variation in plant height across the field. Note: only the RWA transect showed VSI.

Figure 12: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" uncovered transects.
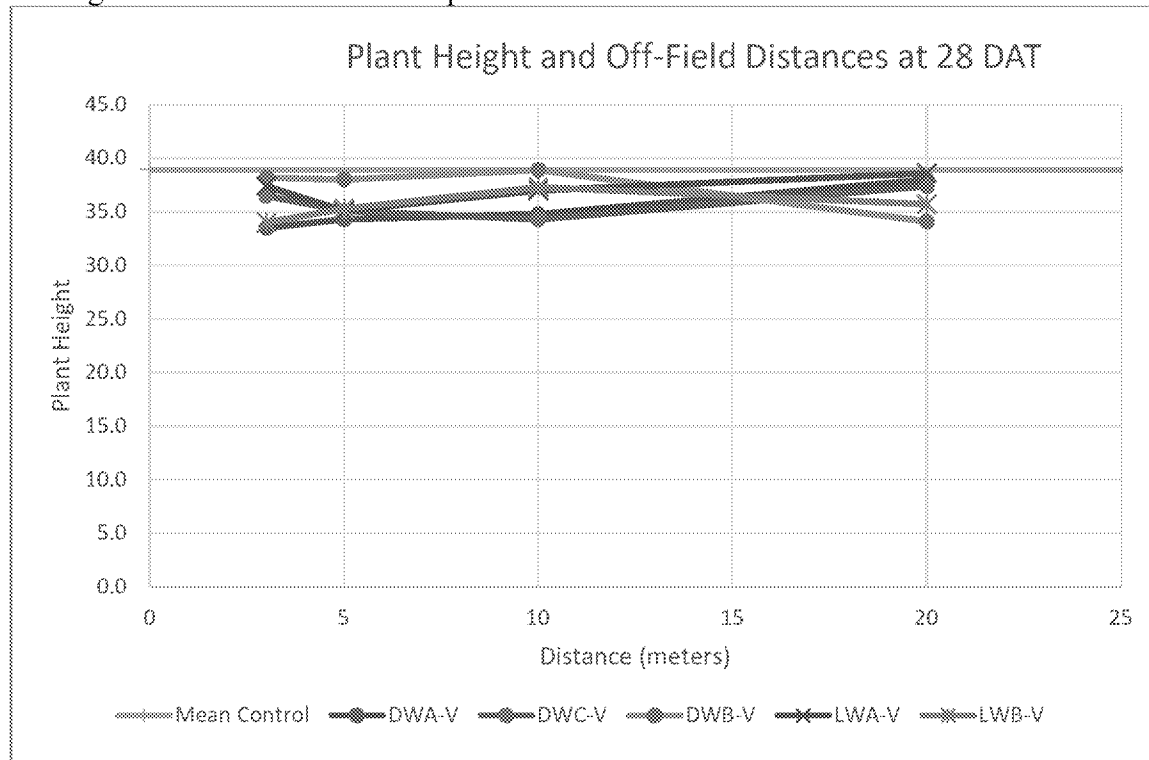

Figure 13: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "DW" and "LW" covered transects.
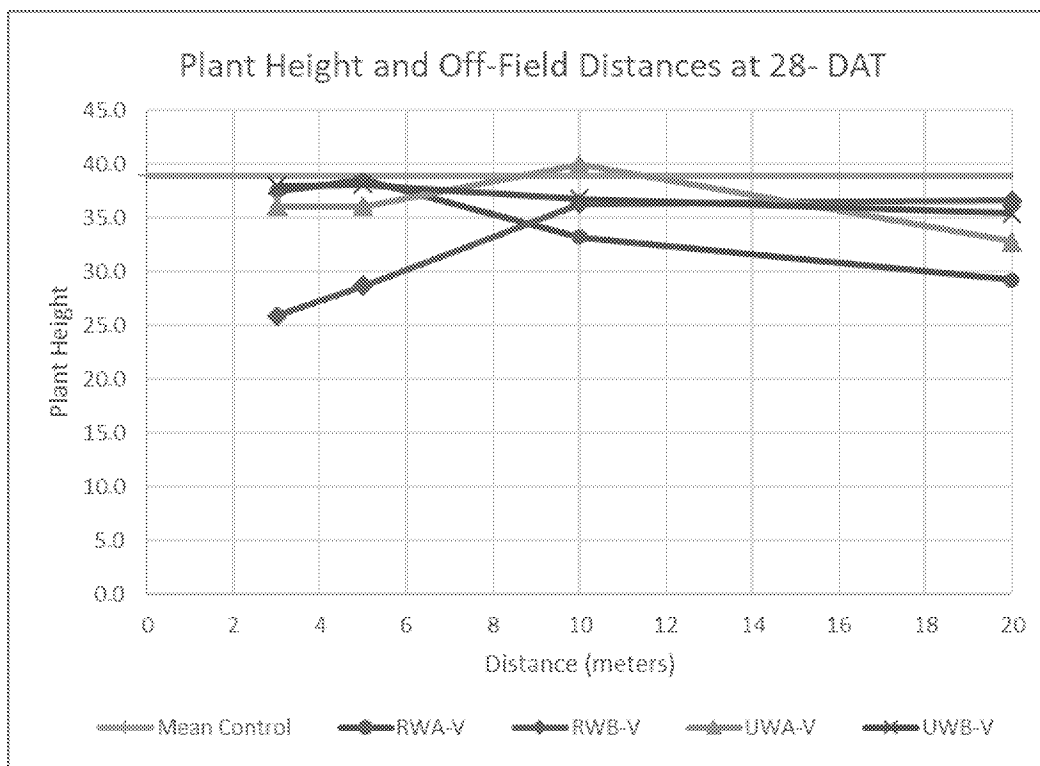
Plant Height and Off-Field Distances at 28- DAT

Figure 14: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "RW" and "UW" covered transects.
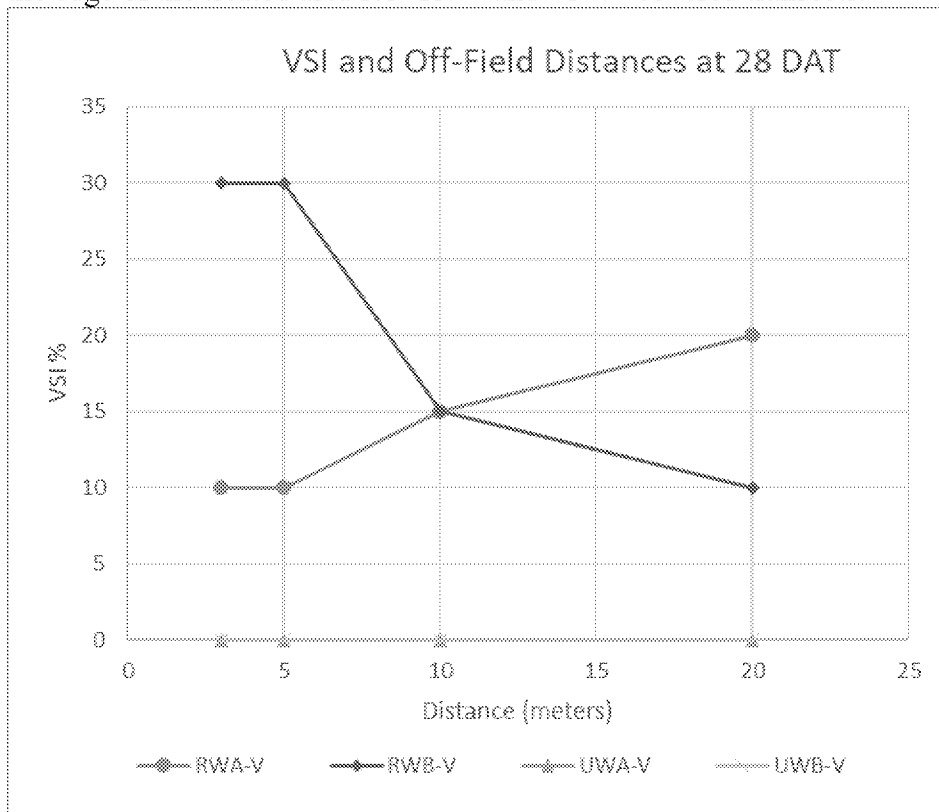
VSI and Off-Field Distances at 28 DAT

Figure 15: Regression of %VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "RW" and "UW" covered transects. Note only RW transects showed VSI.

III. Study Deficiencies and Reviewer's Comments

1. The registrant used a different approach to calculate Z_p, the top of the concentration plume, than that recommended by EPA when calculating volatilization flux rates using the Integrated Horizontal Flux method (Appendix D, p. 532). The registrant used:

$$Z_p = \exp\left(\frac{-D}{C}\right)$$

   C and D are the slope and intercept of the log-linear concentration regression and removed the 0.1 from the equation. The 0.1 represents the concentration at the top of the plume, which is a carryover from the use of this technique for estimating flux rates for fumigants, which typically have much higher concentrations than those anticipated for semi-volatile chemicals like dicamba. The revised equation is acceptable to the reviewer and does not significantly impact the estimate of flux rates.

2. A total of 2.35 in (59.69 mm) of rainfall was recorded during the air sampling portion of the study. Totals of 0.07, 2.01, 0.13 and 0.14 inches of rain fall was recorded during the 0-6, 36-48, 84-96, and 96-108 hour sampling events respectively. While the rain may not have had a major impact for the first 36 hours of the study, it is uncertain how it affected the flux rates for the remainder of the study. It did not impact the deposition portion of the study.

3. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to test site observations, slope estimates, pesticide and crop history, soil taxonomy, and study weather data (p. 3).

4. The first air monitoring period started after the conclusion of application.

5. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

6. Soil bulk density and organic matter content were reported at only a single depth of 0-6 inches.

Study Deficiencies: Plant Effects

1. For both the volatility and spray drift portions of the study, the study author measured the height of a varying number of plants along each transect prior to test material application (volatility n=2; drift n=3; Appendix G, Table 1, p. 733). Following application, "At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points" (Appendix G, p. 727).

   The variability in plant vigor and stand condition across the site suggested the results of both studies may have been confounded due to a lack of homogeneous field conditions.
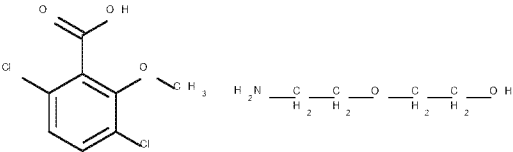
The method presented by the study author indicates that no effort was made to determine uniform, homogenous, boundary-marked sampling sites at prescribed distances and sampling areas prior to treatment. OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. Although the study author reported that 'plants selected for plant height measurements were selected non-systemically as an unbiased representation for the population", the reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

2. Rainfall throughout the study was observed to have pooled in areas of low elevation. Subsequent growth effects due to flooding in some portions of the test fields were reported. The variable impact of the flooding on plant growth may have additionally confounded test results.

3. In certain cases, environmental factors were an important variable influencing plant height. For example, in the north diagonal drift transect (0% symptomology) and left wind B drift transect (15% symptomology), plant height was negatively impacted; however, reduction in plant height was likely attributable to standing water in the field and is not considered treatment related (Figure 7). Based on the information provided for VSI it is not possible to discern dicamba related VSI from other influences. Therefore, the reviewer considered all VSI reported in the study to be a response to dicamba exposure.

4. Transects for spray drift were 60 m long (three upwind sides and two diagonals) and approximately 120 m long (downwind side and the two downwind diagonals) with measurements/symptomology ratings completed at approximately 3, 5, 10, 20, 40, 50, 60, and 120 m from the sprayed area. The study did not report actual distances for each of the height measurements.

5. The study author did not provide seed supplier information and historical germination rates for the soybean varieties planted.

6. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported, nor was the specific location within the untreated field as it relates to elevations.

7. The physico-chemical properties of the test material were not reported.

8. The Stine PGL3590 variety of soybean that was planted in the test plots for both the volatility and spray drift study, is a non-Dicamba tolerant soybean. This variety was also selected because of its glyphosate-tolerance. It is uncertain if this genetically modified variety may have impacted dicamba effects compared to a non-genetically modified variety.

IV. References

Johnson, B., Barry, T., and Wofford P. 1999. Workbook for Gaussian Modeling Analysis of Air Concentrations Measurements. State of California, Environmental Protection Agency, Department of Pesticide Regulation. Sacramento, CA.

Maher, D. 2016. Storage Stability of Dicamba on Polyurethane Foam Air Sampling Traps. Monsanto Technical Report MSL0026782. St. Louis, Missouri.

Majewski, M.S., Glotfely, D.E., Paw, K.T., and Seiber, J.N. 1990. A field comparison of several methods for measuring pesticide evaporation rates from Soil. Environmental Science and Technology, 24(10):1490-1497.

Wilson, J.D., and Shum. W.K.N. 1992. A re-examination of the integrated horizontal flux method for estimating volatilisation from circular plots. Agriculture Forest Meteor. Vol 57:281-295.

Yates, S.R., F.F. Ernst, J. Gan, F. Gao, and Yates, M.V. 1996. Methyl Bromide Emissions from a Covered Field: II. Volatilization," Journal of Environmental Quality, 25: 192-202.

Attachment 1: Chemical Names and Structures

Dicamba-diglycolamine and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba-diglycolamine (Diglycolamine salt of dicamba)	IUPAC: 3,6-Dichloro-o-anisic acid-2-(2-aminoethoxy)ethanol CAS: 2-(2-Aminoethoxy)ethanol;3,6-dichloro-2-methoxy-benzoic acid CAS No.: 104040-79-1 Formula: $C_{12}H_{17}Cl_2NO_5$ MW: 326.17 g/mol SMILES: COc1c(Cl)ccc(Cl)c1C(=O)O.NCCOCCO		835.8100 Field volatility	51111901	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means "applied radioactivity". MW means "molecular weight". NA means "not applicable".

Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Validation spreadsheet for the Indirect Method

    128931_51111901_DE
    R-Fate_835.8100_Indir

2. Validation spreadsheet for the Integrated Horizontal Flux and Aerodynamic Methods:

    128931_51111901_DE
    R-Fate_835.8100_ AD I

3. Air modeling files

    **128932_51111901_DE
    R-Fate_Air Modeling F**

4. Validation spreadsheet for spray drift calculations
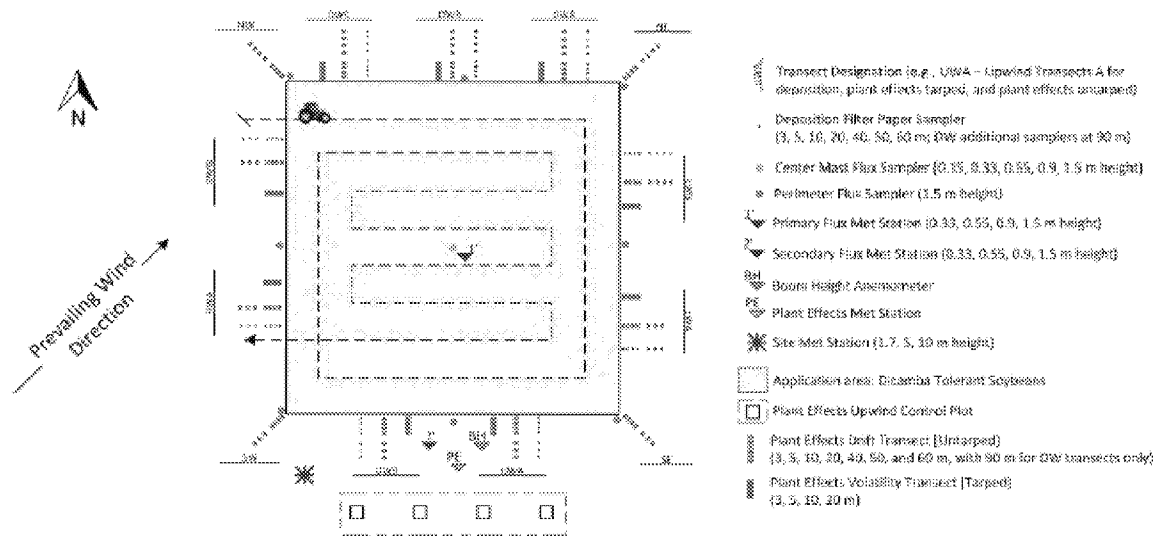
    128931_51111901_DE
    R-Fate_840.1200_08-2

5. Terrestrial Plants: Regressions for Plant Height and VSI

    Plant Effect
    Distances.xlsx

Attachment 3: Field Volatility Study Design and Plot Map

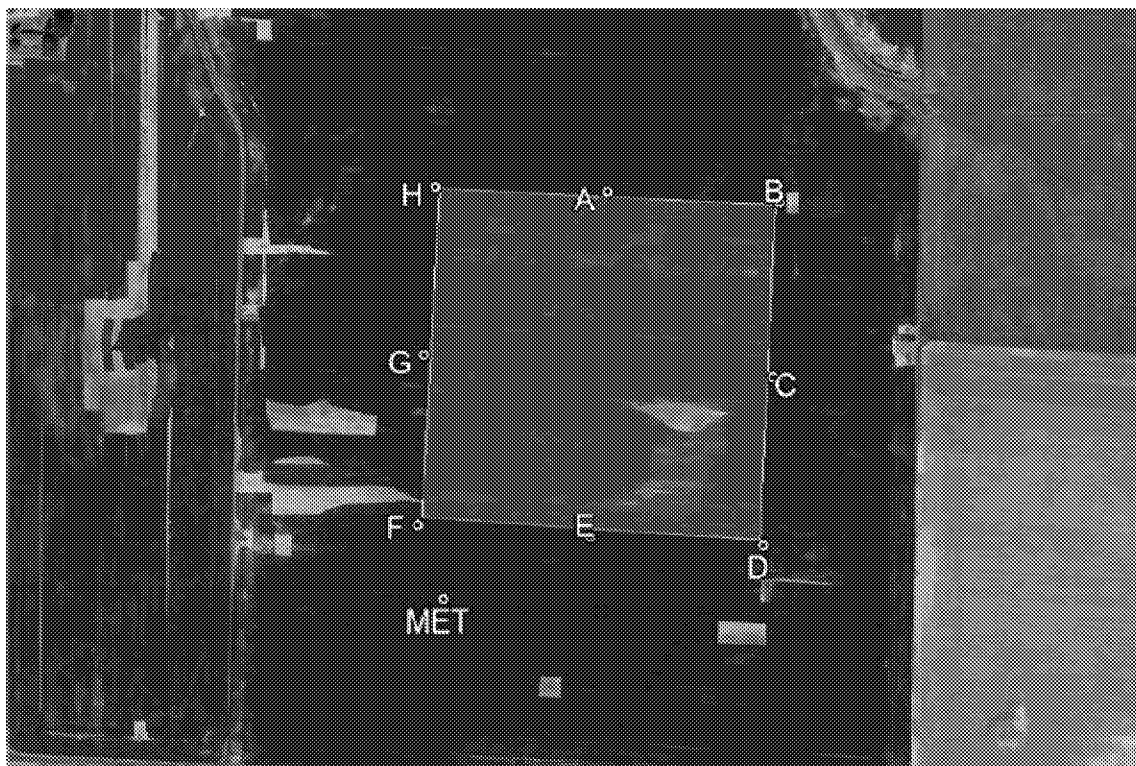Source: Will Griese, Monsanto Company, March 30, 2020.

Figure obtained from Appendix H, Figure 1, p. 582 and Appendix F, Figure 2, p. 510 of the study report.